University of Colorado
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Lyotropic Liquid Crystal (LLC) Nanofiltration Membranes

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IP Status:

Issued and pending patents; available for exclusive or non-exclusive licensing.

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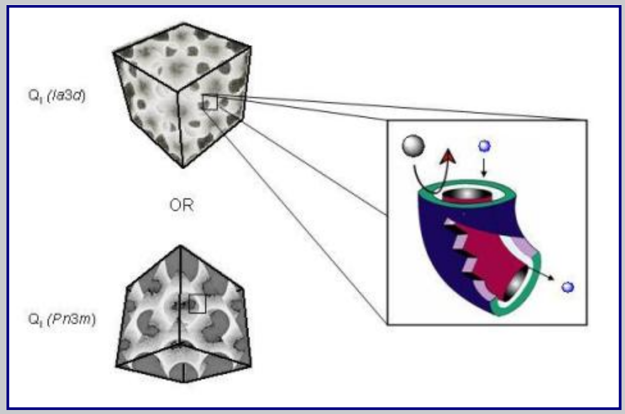
Ref. # CU2412B, 1642B, 1012B

Background

The efficient recovery of fresh water from salt water or waste water is of paramount importance in arid regions, highly industrialized regions, and coastal regions without a fresh water source. Commercially available membrane desalination and purification technologies, including reverse osmosis (RO) and nanofiltration (NF), have limited feasibility due to high energy requirements, limited selectivity, and chemical instability.

Technology



University of Colorado research groups led by Douglas Gin and Richard Noble have developed a novel type of water filtration membrane based on the polymerization of lyotropic liquid crystals (LLCs) that contains ordered, densely packed, size-tunable pores of uniform size. These new LLC membranes have pore sizes on the order of 0.5-2 nm. The resulting size-selectivity of these membranes enables high, predictable rejection of dissolved ions (salts, in particular) from water as well as a number of organic molecular solutes. In this way, these novel membranes combine the best filtering characteristics of both RO membranes (removal of ions) and nano-filtration techniques but with additional advantageous feature not present in either type of conventional water purification membrane.

LLC Membranes: Novel Characteristics and Advantages

Control of membrane pore structure is a major challenge for membrane manufacturers. Of all available technologies, only RO or dialysis polymer membranes have "pores" in the size range of these novel LLC membranes. However, RO and dialysis membranes do not have uniform pore sizes, nor are they ordered, densely packed, or size-tunable. Additionally, traditional membranes are often chemically unstable, and degrade readily upon exposure to certain chemicals.

Advantages of LLC membranes include:

- ⇒ Sub-1-nanometer-scale, uniform, and tunable pore sizes
- ⇒ High pore density
- ⇒ Controlled pore environment
- ⇒ Tunable chemistry inside the nanopores for enhanced chemical selectivity
- ⇒ Capable of both size-selective and chemical-selective separation
- ⇒ Reduced pressure operation (lower energy cost)
- ⇒ Resistance to chemical degradation (e.g. chlorine)
- ⇒ Resistance to non-specific protein fouling

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Fabrication Process

Douglas Gin's group has refined, simplified, and reduced the cost of LLC monomer synthesis. Their proprietary monomer forms a LLC phase in the presence of water that is characterized by 3D-interconnected, ordered, monodisperse, aqueous nanopores. These pore characteristics make this material particularly suitable for water filtration. The material containing the ordered LLC can be cast into thin films and subsequently photopolymerized into a cross-linked network while retaining the desired LLC phase structure. In most cases, the LLC monomer mixture is applied to existing porous substrates to form a composite membrane after *in situ* polymerization.

Applications

These novel LLC membranes have shown excellent results in water desalination, but they also have many other potential applications. Separation applications of these nanoporous LLC membranes include:

- ⇒ Water desalination
- ⇒ Purification of produced water
- ⇒ Water purification
- ⇒ Industrial feed steam purification
- ⇒ Gas separations
- ⇒ Biofuels and bio-process mixture separations
- ⇒ Solvent regeneration

ALD Modification

These LLC membranes can be modified by inorganic atomic layer deposition (ALD) to reduce pore size and, optionally, alter the chemical selectivity of the membrane. This modification is tailored to the chemistry of the original LLC membrane. An LLC membrane modified in this way can be used to separate smaller gas particles like (O_2 from N_2) and (H_2 from CH_2) with a potential use in coal fired plants to feed pure O_2 into the furnace, making the process more efficient and yielding a pure outgas stream of CO_2 which would enable easier sequestration.

Patent Documents

"Nanoporous, Bicontinuous Cubic Lyotropic Liquid Crystal Networks via a New Polymerizable Surfactant Platform." Provisional patent application filed Jan. 25, 2011; available under CDA.

Lyotropic Liquid Crystal Nanofiltration Membranes. U.S. Patent 7,604,129 issued Oct. 20, 2009.

Lyotropic Liquid Crystal Membranes based on Cross-linked Type I Bicontinuous Cubic Phases. U.S. patent application filed May 15, 2008.